

Modeling natural fractures using borehole and outcrop data

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Summary

The modeling of natural fractures is important in the context of CO₂ storage for two primary reasons. Firstly, fracturing of the cap rock possibly due to increased injection pressure may lead to the unwanted leakage of CO₂. Secondly, and particularly for tight reservoir formations, fractures represent critical fluid flow pathways and constitute a large fraction of the total storage volume. We here present a model of natural fractures in a reservoir constructed using both borehole and outcrop data as input. This work is part of ongoing work aimed at studying the feasibility of CO₂ sequestration on Spitsbergen, Svalbard.

Introduction

Natural fractures have a large impact on the fluid flow through a reservoir (Questiaux et al. 2010, Wennberg et al. 2008). Their presence may be beneficial, in that fracture systems can increase the permeability, but also detrimental, in that extensive fracturing of the cap rock may facilitate fluid escape. In view of the planned increased use of the subsurface for the storage of CO₂ (Bachu 2008), the integrity of the seal with respect to fracturing is critically related to both the amount of injectable CO₂ and the pressures at which CO₂ is injected. The study of fractures is particularly critical in tight reservoirs, such as the Longyearbyen CO₂ lab, where permeability, and thereby injectivity and storage potential, is governed by fractures (Braathen et al. submitted).

As part of the Longyearbyen CO₂ laboratory project, part of the CO₂ captured from the local coal-fuelled power plant is planned to be injected into a Triassic/Jurassic siliciclastic succession of the Kapp Toscana Group (Braathen et al. submitted). Burial and subsequent erosion has led to extensive cementation and compaction of the proposed reservoir unit, resulting in a matrix permeability of up to 2mD (Farokhpoor et al. 2010). Water injection tests, however, suggest a higher injection potential with a total flow capacity on the order of 45 mD·m in the lowermost, least-permeable, 100m of the reservoir (870-970m). The presence of fractures is deemed responsible for this injection potential.

The accurate representation and understanding of natural fractures in reservoir models is critical for dynamic flow simulations to predict the behaviour of CO₂ in the subsurface. In recent years, industry-standard software (e.g. Schlumberger's Petrel and Roxar's RMS) have developed modules allowing for the representation of both discrete and implicit fracture sets. Due to the highly variable nature of fractured reservoirs, field-specific measurements at multiple scales must be gathered in the area of interest. In this contribution, we intend to highlight the representation of natural fractures within the Kapp Toscana Group siliciclastic unit of Spitsbergen, Svalbard. The core-based characterization of these fractures is extensively covered in a separate contribution by Ogata et al (submitted) and we here focus on optimising the digital representation of these fractures in view of ongoing flow simulations.

Methods and preliminary results

As described extensively by Ogata et al (submitted), fractures were manually logged in the reservoir interval (672-970m) and classified on the basis of their dip, appearance and possible cementation.

Figure 1 illustrates the workflow from borehole data (A) and outcrop data (B), via analysis of fracture orientations (C) to the implementation of both discrete and implicit fracture sets in the reservoir model (D) which are upscaled in the final reservoir grid (E). A short field reconnaissance was conducted in late May 2011, focussing on gathering data on fracture data not available from the borehole (primarily fracture orientation, fracture length and lateral fracture continuity). Snow cover of critical outcrops allowed the collection of only two fracture scanlines, though a longer field campaign is planned for July/August 2011. Flow simulations in a near-well model are initially planned, aimed to history match a water injection test conducted in August 2010. Subsequently, larger-scale flow simulations are envisioned to predict the behaviour of injected CO₂ in the subsurface. Preliminary results suggest that fractures align both parallel and perpendicular to the main compressional stress field oriented approximately NE-SW.

Conclusions

The accurate representation of natural fractures is critical in the generation of precise geological models. We here present the application of reservoir modelling to represent natural fractures critical to potential CO₂ injection into a tight siliciclastic unit of the Kapp Toscana Group on Spitsbergen, Svalbard. The ongoing study attempts to address several key questions, notably addressing the injectivity and storage potential of the reservoir unit.

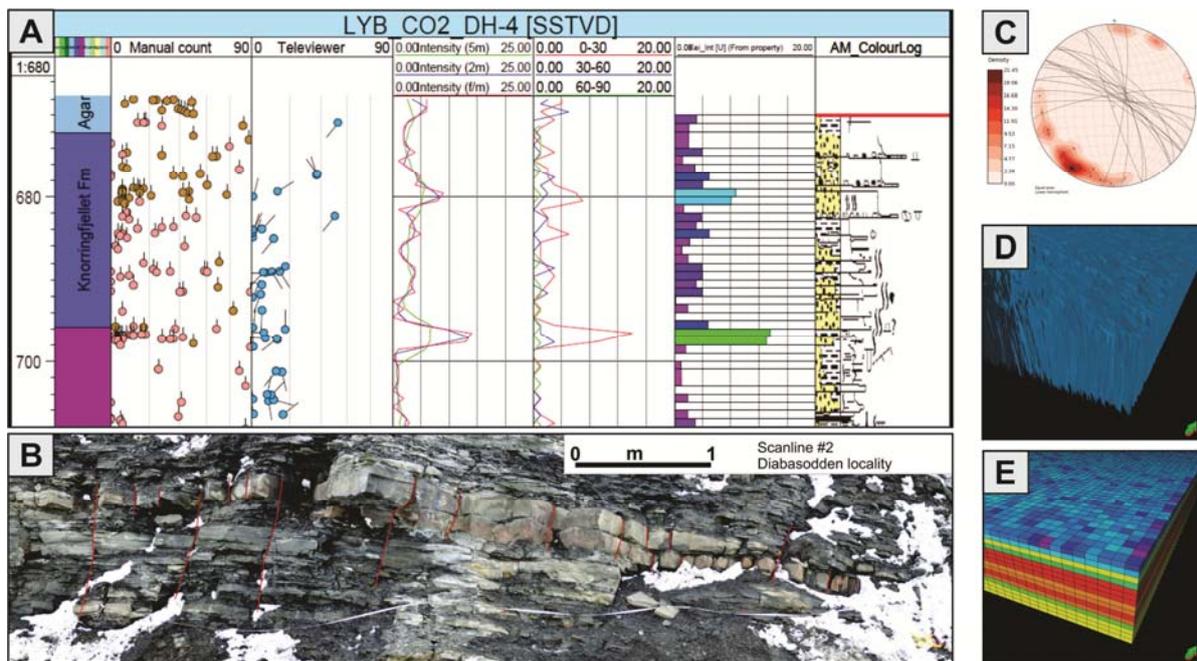


Figure 1 Workflow from borehole and outcrop data to the reservoir model. A) Well section showing individual fractures as well as the derived intensity curves for the Knorringfjellet Formation (target reservoir) of borehole LYB_CO2_DH4. The intensity value is directly correlated to the reservoir model. B) Photograph of the lower part of the reservoir, the De Geerdalen Formation, taken some 15 km from the borehole at Diabasodden. Natural fractures are marked in red. C) Stereonet showing orientation of the measured fractures. D) Example of a suite of fractures represented in the reservoir model. E) Upscaled fracture properties (permeability) as represented in the grid.

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(<http://co2-ccs.unis.no>). Schlumberger provided an academic license for Petrel and ECLIPSE, while Roxar provided an academic license for RMS. Fieldwork on Svalbard has been partially funded by an Arctic Field Grant from the Svalbard Science Forum. Romain Chesnaux gratefully outlined the methodology of using scanline data in Petrel. Atle Mørk provided the sedimentary log presented in Figure 1.

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